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Energy balance, forecasting of bioelectricity generation and greenhouse gas emission balance in the ethanol production at sugarcane mills in the state of Mato Grosso do Sul

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ABSTRACT

The aim of this paper is to present aspects about the energy balance of sugarcane crops and its carbon dioxide emissions. We calculate energy used in agricultural, industrial and distribution sectors by five sugarcane mills of Mato Grosso do Sul and we compare the yield with its energy delivery. The energy balance obtained, with an average 6.8, shows that is advantageous to produce ethanol in the lands of that Brazilian state. We have prepared a forecasting of electricity production from bagasse taking into account two types of technology. Finally, we present the potential value of CO_2 emitted by the five mills to evaluate greenhouse gas emissions of the ethanol production valor chain.

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1. Introduction

Currently there are clear evidences about depletion of non-renewable energy sources and their contribution to greenhouse gas (GHG) emission [1]. Fossil fuels and their prices have a tendency to rise each year. Nevertheless, oil fuel is the one moving the world still. Global oil consumption is over 87 million barrels per day and in keeping with its historical rate of growth (1.4%), oil demand will reach 120 MM at the end of 2011. Such demand will have an impact over current reserves, forcing a short-term exploration. Therefore it is important to find a substitute for fossil fuels. Biofuels are emerging as possible substitutes, and countries like Brazil and United States hold expertise and technology to produce ethanol, Brazil from sugarcane and US from corn. Biodiesel is being seen as a good alternative to substitute mineral diesel in the transportation sector. However, in Brazil, the scale production is restricted.

Ethanol or bioethanol, its most recent denomination, is a green fuel because the growing sugarcane crops function as a sink of CO_2,

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therefore contributing to the reduction of GHGs. However, even in the case of a renewable energy source, it is appropriate to evaluate the yield and useful cycle of ethanol production as a whole to properly assess the potential environmental benefits as well as the consequences of its consumption and production.

Munashinge [3] affirms that any economic activity can follow the precepts of sustainable development, the preconditions of which are the co-existence between economic, social and environmental systems providing opportunities to improve these systems and increasing adaptive capacity. The pursuit of economic progress is not just an adequate interpretation of environmental and social sustainability. Economic progress should overlook the failure of any medium and long-term programs and contemplate future liabilities under heavy environmental degradation and social breakdown. Data from UNCTAD, United Nations, that reviews and implements programs of a social and environmental nature, say that there is a close relationship between poverty and deterioration of the environment [4]. Moreover, the privatization policy of the nineties has extended distances between rich and poor nations and internally between rich and poor classes. The lack of state policies and their implementation shy at the convergence of social goals to mitigate the growing poverty, and in developing countries it has led to an increased pressure of population on environmental systems, increasing their vulnerability and risk of disappearance.

It should be noted that the environmental interpretation of sustainability focuses on the overall viability of the health of ecological systems—defined in terms of detail, dynamic, hierarchical measure of recovery, force and organization. The degradation of natural resources, pollution and biodiversity loss are lethal because they increase the social vulnerability, undermine the ecological health and reduce its resilience [5,6].

2. CO_2 emissions in agricultural activity

Analysis of samples taken from the existing core of underground ice in Greenland and Antarctica has given a clear idea about the variations of CO_2 concentration in the atmosphere since the end of the last ice age. This concentration has increased gradually from 200 ppm to 275 ppm last millennium, before the start of the industrial age. Since then, there was an increase, reaching 366 ppm by the end of the twentieth century, which shows a significant increase in the last 250 years, with emphasis on the last two decades which has seen a more rapid and persistent change.

Surveys show that pre-industrial levels of CO_2 were estimated in the range of 260–285 ppm, while levels measured between 1958 and 1990 have indicated values of 315–353 ppm. Recent records for 2007 showed values of 387 ppm. The global emission of carbon dioxide from the burning of fossil fuels has been estimated at 5000 M mt (metric tons) a year, while changes in the biota of the Earth (destruction of forests and grasslands and desertification) contribute 1600 tm M per year CO_2 [4].

The potential carbon sequestration of terrestrial ecosystems depends on the type and condition of the ecosystem, i.e. its species composition, structure and in the case of forests, the age distribution. Furthermore, there are also important local conditions including climate, soils, natural disturbances, and management.

In agricultural land the biggest portion of carbon is stored underground. Losses of carbon from terrestrial systems over the past 200 years, mainly from the mid-20th century, occurred as the result of the establishment of agriculture and pasture lands that were previously forested. The constant plowing, planting and harvesting have led to an enhancement of the oxidation of organic matter in soil, which has been emitted to the atmosphere as carbon dioxide. Today, agricultural lands are major sources of CO_2 emissions in many countries as a result of changes in the use-of-land. Organic carbon in soil is declining in many areas of the world; the use of fertilizers, plant varieties, high-performance, waste management and reduced care for erosion control has contributed to stabilization or increase in soil organic carbon [7,8].

Sustainability in the exploration and use-of-land (activity that goes beyond agricultural activities) now earns global significance for several reasons: the production and supply of food for a population, which in 2041 will be nine billion people around the planet, the finite resources offered by the planet and especially the availability of water, a vital component for life on Earth. It is necessary to combine all of these factors for practical use-of-land: the predominance of monocultures, the increase of plantations on forests and other ecosystems, endangering its preservation, and finally the loss of biodiversity resulting from this inexorable advance by land. As you know, all human activity will always be in conflict with environmental issues, and adds to the probable loss of ecosystem (or environmental) services supplied by them.

Moreover, some outdated procedures of intensive agricultural practices such as inappropriate land management and the extensive amount of nutrients, herbicides and insecticides should be reviewed, taking into account their huge environment impact. Energy crops monocultures like sugarcane, corn, eucalyptus, and others already identified in the production of biofuel crops can have serious social and environmental damage if not handled with sustainable criterium because of its typical characteristic.

Energy from biomass can be used to mitigate greenhouse gas emissions from fossil fuels, and are currently also able to provide equivalent final energy services such as, electricity, transport fuels and heat. The avoided emissions of CO_2 from fossil fuels are equal to the fossil fuel replaced by biomass energy service less fossil fuel used in biomass energy system. These quantities can be estimated with an analysis of the fuel cycle completely.

3. Energy inputs in the production of ethanol

The energy choice is usually made based on two predominant factors: the investment cost and cost of energy production. However, from the late eighties and early nineties the consideration of the environment, including degree of local pollution, emissions of greenhouse gases, pollution of water bodies and/or groundwater, damage to biome, etc., was added up [9]. The finding of several studies and research on the imminent exhaustion of fossil fuels as an energy source, is leading a desperate search for energy sources that can partially replace the drop that should occur in the fossil energy supply.

The global energy matrix shows that renewable energy, including solar, wind, hydro, tidal and biomass, have remained in the range of 10%–15% (Table 1) of the total world energy consumption [2]. By the end of the last century, biomass consumption in the world accounted for 14% in Latin America, Africa and southeast Asia. This source of energy was based mainly on the firewood consumption. Biomass consumption was seen as synonymous to backwardness; it was preferably employed for poor and rural populations. Moreover, it is an inefficient energy due to the low

Table 1
Share of renewable energy in global energy consumption.

	1973	2000	2003	2050
Energy global consumption, Mtoe	6040	9963	10,579	22,300
Share of renewable energy (%)	11.1	11.0	10.8	9.0

utilization of raw material in the transformations in furnaces and boilers. Additionally, it is linked to processes of deforestation and desertification due to human activity; besides, it should be noted that the use of charcoal is significant in mineral processing industries (aluminum, pig iron, etc.) [3].

However, the use of bioenergy is emerging with force in the world, in some cases in a sustainable manner and in other cases as predatory and destructive forms. Because there is a wide variety of bioenergies (biofuels and bioelectricity) and a wide variety of production systems using them impacting differently on social, environmental and economic issues, it is imperative and necessary to analyze the boom of bioenergy production over the entire value chain.

Along the ethanol chain many inputs are needed for its production. From preparing the land where the use of chemical potassium, phosphorus and nitrogen and herbicides is needed including the transportation of cane to the mill and entire manufacturing process because both require expenditure of energy in various forms. According to Refs. [10,11], for a right computation of the energies involved in the agro-industrial production it is necessary to consider the emissions of greenhouse gases (GHG) associated with its life cycle, both of the burn combustion in agricultural operations as in the production and use of fertilizers.

The production of sugar and ethanol from sugarcane requires energy processes, but has the peculiarity that CO_2 emissions are zero, since it closes the circuit between the fuels required for power and thermal supply processes (Table 2). The mills demand for energy comes from sugarcane, in the form of fiber, which becomes bagasse after extraction of juice. Mills self-sufficiency could be a reality since 145 kg of sugar and 140 kg of fiber can be extracted from each ton of cane, and there are other 140 kg of fibers associated with the leaves and stems [12,19].

To understand better the energy balance methodology broadcasted we compare two references much known in energy balance of ethanol production from sugarcane [13,14]. It is possible to observe that the principal divergence between the researchers is the high value of diesel demand in the sugarcane transportation inside sugar crops and the energy spent by some equipments of the industrial sector calculated [13]. Energy balance done by Ref. [14] has more items that those analyzed by Ref. [13].

The assessment of greenhouse gas emissions mitigation, through the rate of carbon dioxide equivalent emission is the result of the mills energy balance analysis, located specially in São Paulo state [13,14,17,20]. It must be stressed that in calculating the balance of carbon dioxide, the authors considered all the CO_2 emissions along the production chain of ethanol, since it is understood that the cycle of emission of carbon dioxide in ethanol production is closed because it is assumed that the CO_2 released will be sequestered and utilized by photosynthesis for growth of biomass for the next harvest. Two authors in Refs. [13,14] have accounted the CO_2 emissions released due to methane, nitrous oxide and ethanol distribution from sugarcane distillery plant to the distribution stations. The CO_2 equivalent emissions for methane, nitrous oxide and distribution of ethanol are considered standard for all units in our study; this hypothesis is also assumed by authors in Refs. [13,14,17] in their respective studies on greenhouse gas emissions from sugarcane mills.

Table 2
Conversion factors to calculate energy balance.

Item	[13] Energy demand (MJ)	[14] Energy demand (MJ)
Nitrogen	57.5 per kg	56.3 per kg
Phosphate P_2O_5	7.03 per kg	7.50 per kg
Potassium oxide K_2O	6.85 per kg	7.00 per kg
Lime seed	1.71 per kg 15.6 per kg	0.10 per kg -
Herbicides	266.56 per kg	355.60 per kg
Insecticides labor	284.82 per kg	358.80 per kg 0.11per worker
Diesel fuel	–	38.30 per m^3
Industrial sector	3.63 GJ per ha	3.71 GJ per ha
Transportation	2.82 GJ per ha	4.00 GJ per ha

4. Energy balance of the ethanol production mills at Mato Grosso do Sul

The methodological approach consists in investigating the energy consumption inserted in the nutrients, insecticides and herbicides production. It is necessary to know the energy spent in the work done by cutters and finally how much diesel fuel is consumed per hectare of sugarcane planted. The details of the quantities of inputs per hectare, the equivalent energy factors and total energy consumed per hectare of the plant average assessed are given in Table 2. The calculation is done using conversion factors according to those published in [13].

The database to the energy balance calculated has been obtained from five mills in Mato Grosso do Sul (MS) which were willing to provide information. The mills provided data about sugarcane crops area and quantity of inputs used to cultivate (Table 3). The database bank built came from a survey designed to assess consumption of inputs per hectare, and the ability of a plant to produce ethanol. However, it should be noted that the accuracy and quality of information were very heterogeneous. The column of energy equivalent corresponds to energy demand for each component per kilogram (GJ kg^{-1}), per worker (GJ per worker) or per cubic meter of diesel fuel spent in the soil preparation, harvesting and production of the ethanol. Conversion factors used to calculate equivalent energy have been extracted from Ref. [13], except for labor and diesel fuel items, which came from Ref. [14].The requested data on the energy balance are based on items listed in Table 2. Sugarcane mills directly or indirectly provided ten items data in which components used are kilogram per hectare (kg ha^{-1}), number of workers at mill and diesel fuel used per cane crop.

Assuming that the productivity of sugarcane crops at Mato Grosso do Sul is 75.0 t per hectare, information sustained in Refs. [12,15], we carried out the energy balance calculations. To measure energy the values were multiplied by the amount of input for use by each plant in particular the energy demand of this input. The result is the energy cost per ton of cane for each component (GJ ha^{-1}). The output or production of energy supplied by the mill, in all cases, is the product of the ethanol low heat value (LHV) 22.4 MJ l^{-1} [16], sugarcane productivity (75 tc ha^{-1}) and ethanol production by sugarcane ton (80 L t^{-1}) that results in 134,4 GJ ha^{-1}.

Table 3
CO_2 released (kg) by unit of constituent in bioethanol production.

Constituent	[13]	[14]
Nitrogen	3.14 per kg	3.97 per kg
Phosphate P_2O_5	0.61 per kg	1.30 per kg
Potassium oxide K_2O	0.44 per kg	0.71 per kg
Lime	0.13 per kg	0.01 per kg
Herbicides	17.24 per kg	25.0 per kg
Insecticides	18.08 per kg	29.0 per kg
Diesel fuel	3.08 per Liter	–

The values of energy expenditure or energy required together with energy generated or delivered by the mills are shown in Tables 5 and 6. The energy delivered by a mill could, sometimes, be through three products: ethanol, bagasse surplus and electricity surplus. In our analysis of the Mato Grosso do Sul mills the only data available was the ethanol production, so the other two are not considered in this balance.

As the ethanol production has been the only value accounted as energy delivered by the mill to calculate the energy balance, it is divided by the energy required or expended so we can obtain the energy balance, which is a dimensionless value. The energy balance average value is 6.8 for the five mills evaluated. These values are summarized in Table 4 and the interpretation is that the energy supplied by mills in the form of bioethanol fuel is greater than the energy expended by the same mills to produce ethanol. Ref. [14] disclosed the average value of 8.3 of the São Paulo mills assessment. On the other hand, Ref. [13] obtained an average ratio of 3.7. In our study carried out for five mills of MS, the highest value was in the Santa Helena plant, in which for every unit of energy expended in the production of ethanol it delivers 7.7 units of energy. This means that there is a low cost of energy inputs used in the preparation of soil for sugarcane production and its conversion process. The Santa Helena plant, as well as fourteen other new mills, has been installing new and advanced technology to produce ethanol. In conclusion, we can say from the point of view of energy balance that to produce ethanol in the lands of MS is very advantageous and competitive. Other similar studies outside those already mentioned about mills energy balance allocated at São Paulo state disseminate values very close to those obtained in our energy balance [17].

5. Potential electric energy production from sugarcane mills at Mato Grosso do Sul

In bioethanol process conversion, nowadays, most of the mills are self-sufficient in terms of production and consumption of energy (thermal, mechanical and electrical). Electricity demand comes from burned bagasse at the boiler of a cogeneration system. According to Ref. [12], on average in Brazil, the mills generate 12 kWh of electricity per ton of bagasse burned, and 16.0 kWh of mechanical energy and 330.0 kWh of heat energy in the processes. However, mills that are more efficient and have more advanced technology, such as the San Marino plant, generate approximately 18.0 kWh per ton, or equivalent to 64.7 MJ as has been reported in Ref. [13].

The GDP of Mato Grosso do Sul contributes, on average, 1.15% of Brazilian GDP, which was US$ 2172 billion in 2010 [18]. Considering the average rate of Brazilian GDP we made a forecasting of the MS′ GDP for the next ten years. Additionally, we know that the greatest amount of sugar and alcohol mills to be built in the state MS must happen from 2008 to 2015. In the past ten years electricity consumption has grown at an average rate of 2.8% in MS. We set the correlation between electricity

Table 4
Sugarcane mills database in agricultural sector.

Item	Energy equivalent Unity GJ	Usinavi Quantity (kg per hectare)	Angêlica agroenergy Quantity (kg per hectare)	Alcoovale univale Quantity (kg per hectare)	Ldc maracajú Quantity (kg per hectare)	Santa helena Quantity (kg per hectare)
Nitrogen	57.5 per kg	85	40	90	83.17	33.41
Phosphate P_2O_5	7.03 per kg	140	110	165	152.5	167.05
Potassium oxide K_2O	6.85 per kg	125	125	120	145	50.12
Lime seed	1.71 per kg 15.6 per kg	200 2.0	350 0.5	300 2.0	177.3 5.0	250 2.78
Herbicides	266.56 per kg	1.6	4.5	2.5	2.2	2.32
Insecticides labor [a]	284.82 per kg 0.11per worker	0.16 0.047	0.16 0.025	0.16 0.038	0.16 0.054	0.16 0.031
Diesel fuel [b]	38.30 per m^3	171.6	165.4	170	170	167.1
Area	hectare	32,043	30,000	20,000	22,000	24,550

[a] Total number of workers of each mill was divided by the respective area.
[b] Total diesel fuel used was given in liters per month by mill and divided by sugarcane crop area.

Table 5
Energy balance of ethanol production.

Energy consumption (GJ ha^{-1})	Usinavi	Angêlica agroenergia	Alcoovale univale	Ldc maracajú	Energetica santa helena
Nitrogen	4.98	2.30	5.17	4.78	1.92
Phosphate P_2O_5	0.98	0.77	1.16	1.08	1.17
Potassium oxide K_2O	0.85	0.85	0.82	0.99	0.34
Lime seed	0.34 0.03	0.59 0.08	0.51 0.03	0.30 0.08	0.42 0.04
Herbicides	0.42	1.19	0.66	0.58	0.62
Insecticides labor[a]	0.04 0.0001	0.04 0.0001	0.038 0.0001	0.041 0.0001	0.04 0.0001
Diesel fuel[b]	6.57	6.45	6.51	6.39	6.39
Subtotal	14.1	12.2	14.9	14.4	11.0
industrial sector	3.63	3.63	3.63	3.63	3.63
Distribution[c]	2.82	2.82	2.82	2.82	2.82
Total Energy Spent (1)	20.6	18.65	21.35	20.85	17.45
Energy production (GJ ha^{-1})					
Ethanol production	134.40	134.40	134.40	134.40	134.40
Surplus bagasse	0.0	0.0	0.0	0.0	0.0
Surplus electricity	0.0	0.0	0.0	0.0	0.0
Energy production (2)	134.40	134.40	134.40	134.40	134.40
Prod.(2)/spent (1)	**6.5**	**7.2**	**6.3**	**6.5**	**7.7**

[a] Total number of workers of each mill was divided by the respective area and multiplied by the respective factor of energy equivalent (Table 4).
[b] Total diesel fuel used by the mill.
[c] [17] Calculated value of 217.3 kg CO_2 equivalent ha^{-1} assuming an average distance of 500 km between the plants and distribution station.

Table 6
Emissions of carbon dioxide (CO_2) equivalent released in the manufacture and distribution of inputs in ethanol production per hectare (eq. CO_2 kg ha^{-1}).

Constituent	Usinavi	Angêlica agroenergy	Alcovale univale	Ldc maracajú	Santa helena
Nitrogen	266.9	125.6	282.6	261.1	104.9
Phosphate P_2O_5	85.4	67.1	100.7	93.0	101.9
Potassium oxide K_2O	550	55.0	52.8	63.8	22.1
Lime	26.0	45.5	39.0	23.0	32.5
Herbicides	27.6	77.6	43.1	37.9	40.0
Insecticides	2.9	2.9	2.9	2.9	2.9
Diesel fuel	528.5	518.3	523.6	523.6	514.5
Subtotal	1029.7	1183.2	1250.6	1216.2	964.9
Methane[a]	161	161	161	161	161
Nitrous oxide	475	475	475	475	475
Ethanol Distrib[b]	227	227	227	227	227
Vinasse[c]	211.6	211.6	211.6	27.3	1039.7
Filter cake	27.3	27.3	211.6	27.3	1039.7
Machines and Trucks	1554.2	1039.7	211.6	27.3	1039.7
Total	**3123.7**	**3023.9**	**3176.2**	**3137.0**	**2950.4**

[a] Includes installation of the plant, distillery and processing and CH_4 emission of vinasse in the distribution channels.
[b] de Oliveira et al. [13] does not explain this hypothesis, but the values are close to the value published by this author.

consumption and GDP of MS through the linear regression approach and find the following equation—Electric Energy Consumption$=0.0394\times GDP+2.571$ with $R^2=-0.749$. Then, according to this equation our forecasting of electricity consumption between 2009 and 2015 will grow to the average rate of 1.1% per year, so the demand for electricity in MS state is expected to be 4,259,977 MWh in 2020 (Fig. 1).

We develop a scenario of electricity production in which surplus could be sold by the mills. The assumption is that all the mills operating (14) and the new mills to operate (13 mills) should adopt one of the cogeneration systems: the A configuration to reach a production of 57.6 kWh per ton of cane crushed or the B configuration to produce 71.6 kWh per ton of cane. According to our scenario in 2011 the sugar and alcohol plants that adopt this system of cogeneration (57.6 kWh tc^{-1}) would not be able to meet the electricity demand. This negative value indicates that part of the electricity must be purchased from the public utility company. So, around 540,000 MWh would be needed to meet the power demand of the plants. However, this kind of cogeneration system could be reversed from 2015, meaning that the mills would be able to offer 1,778,780 MWh to the state power system network.

On the other hand, if the plants adopt the B cogeneration system (71.6 kWh tc^{-1}), the contribution of the bio-electricity to the grid would be 2,620,090 MWh in 2015 (Fig. 2). It is recalled that in 2015 the projected demand for electricity in the state would be about 4,032,000 GWh (see Fig. 1). Hypothetically, more than half the power demanded in 2015 by MS state could be supplied by the cogeneration system of all the mills. The mills in this case could be categorized as independent power producers (IPP) and be able to participate in auctions of electricity from renewable sources. However, we must take into account that cogeneration systems with high values of electricity by sugarcane ton are very expensive, so old and small mills do not have willingness to invest in these systems.

The fundamental difference between the two technologies under analysis is the reduction of steam consumption in the process. The reduction of 500 kg (system A) for 350 kg of steam (system B) per ton of cane processed (kg tc^{-1}) provides an increase of 24% of surplus electricity. However, it was considered in our assessment that 250 kg of bagasse at 50% humidity are recovered from each ton of cane. Nevertheless, the B configuration requires steam higher temperatures at the cogeneration system because higher pressures are necessary to increase the generation of surplus electric power and this means proportionally higher investments [11].

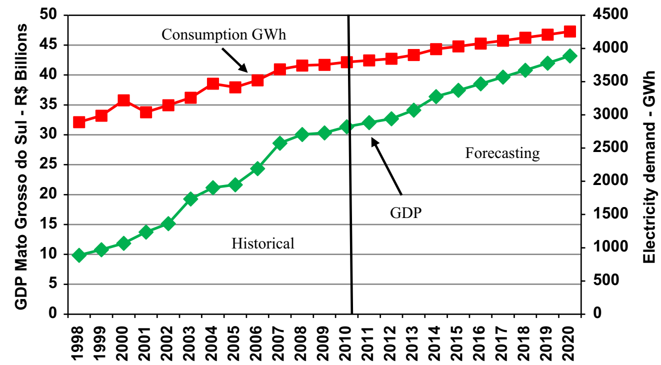

Fig. 1. History and forecasting of GDP and electricity consumption at Mato Grosso do Sul.

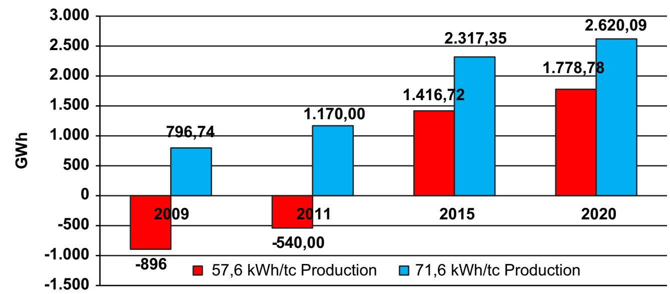

Fig. 2. Scenarios of electric energy surplus produced by sugarcane mills at Mato Grosso do Sul (GWh).

6. CO_2 emissions balance

Ethanol production, as part of the sugarcane industry, is usually presented as a clean product, because in theory, in conversion processes throughout the entire cycle emissions of carbon dioxide released to environment would be reabsorbed by cane crops, completing this way, a virtuous cycle of ethanol production. However, during the manufacture and distribution of inputs used in production of sugarcane there are emissions of greenhouse gases that should be counted in CO_2 emissions. Components such as nitrogen, phosphate, potash, lime, herbicides and insecticides emit greenhouse gases in its manufacturing process, and most of these inputs require the use of petroleum or petrochemical products. Additionally, their distribution from the manufacturing center to the local consumption is done by fleets of trucks that consume diesel fuel, so at this stage also there are emissions of carbon dioxide.

A molecule of methane CH_4 and another of nitrous oxide N_2O have a greenhouse gas potential 21 and 310 times greater than that of carbon dioxide CO_2, respectively, in the atmosphere [1]. Small greenhouse gas emissions during the manufacture of inputs and use of machinery in agricultural operations and processing of sugarcane contribute significantly to the greenhouse effect. In addition, products such as vinasse or sugarcane straw are generating methane [17].

The conversion factors to the emissions are presented in Ref. [13] and they were considered in the calculation of our study. From the data supplied by the mills on the demand for inputs in sugarcane production emissions of carbon dioxide equivalent per hectare were calculated. The CO_2 emissions factor at harvest is unique for all plants and was obtained from the table to calculate greenhouse gas emissions published in Ref. [13] from an analysis of average values of all Brazilian mills. The values obtained for the five sugarcane mills under our study are similar to the ones obtained in Ref. [14], 3244.1 kg of CO_2 equivalent per hectare, so there is a validation of the analysis made in our study of Mato Grosso do Sul.

The calculation of the total greenhouse gases emissions, presented here in the form of carbon dioxide equivalent, is about the energy used in ethanol production. The CO_2 emissions are most abundant during planting of sugarcane, due to the intensive use of heavy machinery and raw materials derived from petroleum. In the growth phase of cane sugar, for significant emissions of N_2O the application of both nitrogen (fertilizer) and organic sources such as vinasse, stillage and filter cake is necessary [17]. The calculations for the five plants were carried out considering thirteen components, eight of which came from information gathered *in loco*, and the five other components that emitted carbon dioxide in the harvest and transportation phase of ethanol production came from the table [13]. The plants that started operations in recent years are those which show the lowest emission of carbon dioxide equivalent per hectare; however, this difference is not significant in relation to older plants with more years of operation. The values of equivalent dioxide of carbon emissions per hectare (eq. CO_2 kg ha^{-1}) due to the methane, the nitrous oxide and the ethanol distribution are respectively, 161, 475 and 227 [13].

According to Ref [21], 145.3 t of CO_2 are sequestered per hectare of sugarcane crop. If the total sugarcane cropped by the five mills is 128,593 ha, then, hypothetically, 18.68 M t of CO_2 are sequestered. During the process of ethanol production 15.9 t of CO_2 are released. Therefore we conclude from the perspective of greenhouse gas emissions during the production of ethanol verified that there is a gain, because the amount of CO_2 sequestered is greater than that emitted.

7. Conclusions

The energy balance of the five plants evaluated shows how positive the activity is to produce ethanol even without considering electricity production. The universe of sugarcane mills analyzed, though not very large, is representative enough to know that the lands of Mato Grosso do Sul are rich for growing sugarcane culture. Moreover, the new plants are willing to adopt the best technology and efficient management in the administration of the whole-crop and the mills [19]. Arguably, the balance of CO_2 emissions from power plants shows that the activity of producing and transporting ethanol is less polluting than any competitor derived from oil, although problems with the use of water in the industrial sector and its return to rivers and, excessive load of vinasse in soil are not still clarified and well resolved.

The production of electricity from bagasse should definitely become one more product of sugar and alcohol mills. The obstacles to adopt the technology to generate more kilowatthour per ton of bagasse are focused on cost specially in regulating of surplus electric energy sales. In Brazil ANEEL (Regulatory Agency of Electric Energy) promotes auctions for the purchase of new energy, where the production of electricity from renewable sources is included. In the last auction while the prices have been very attractive to the plants that produce electric energy from wind to mills, bioelectricity producer prices were not good. The values generated in the attractive scenario of bioelectricity in MS, with the possibility of supplying up to 60% of the electricity demand of the state would change that energy matrix. However, to reach the target of a better scenario it is necessary to make higher investments in the cogeneration technology but not all companies are willing to spend on technology because the bioelectricity market is still incipient.

The diversification of MS energy matrix trough strong inclusion of bioenergy fuels and bioelectricity could give more security to the energy supply. The broad use of cogeneration systems inside sugarcane mills to supply a power demand of the plant and still to produce electricity surplus to market must bring great advantages to the mills and to the MS power grid. Moreover, the state could have a new energy profile and this way it would be in conditions to extend energy services to communities that do not have electricity. However, regulatory aspects about bioelectricity marketing are not well defined yet, because public agencies should fix clear rules in order to assure that power surplus from sugarcane mills are used in the best possible way.

The expansion of sugarcane culture is irreversible and sugarcane mills are obligated to incorporate posture pro-active; this means strong social and environmental commitment in the production of ethanol and bioelectricity. Actually, most of the sugarcane industries are already working with this new point of view, because trade agreements with countries and companies importers of ethanol and sugar require avoiding social and environmental negative externalities. It is imperative that public policies for energy and agribusiness should be cohesive and converged to enhance the exploitation of bioenergy minimizing negative impacts and bringing benefits to the municipalities.

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